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Using rare earths to interpret certain fossils

Until now, interpreting flattened fossils was a major challenge. Now, a new approach for the analysis of such fossils has been developed by a team bringing together researchers from the IPANEMA unit (CNRS / French Ministry of Culture and Communication), the Centre de Recherche sur la Paléobiodiversité et les Paléoenvironnements (CNRS / MNHN / UPMC) and the SOLEIL synchrotron. This non-destructive method makes use of chemical elements known as rare earths. By locating and quantifying such elements in trace amounts, it is possible to improve interpretation of fossil morphology. This enabled the researchers to describe not only the anatomy but also the environment of preservation of three fossils of Cretaceous age. Published on 29 January in the journal *Plos One*, the work should facilitate the interpretation of many flattened fossils, especially those that are exceptionally well conserved.

During the fossilization process, animal and plant remains are frequently flattened and compressed into two dimensions by the pressure of sediments, which sometimes proves to be a real obstacle to the study of such fossils. An added difficulty is that such flattened fossils undergo physical and chemical alteration during fossilization, making it even harder to interpret them. However, such fossils can contain invaluable information. In particular, when their anatomy is well preserved (in which case they are termed exceptionally well-preserved fossils), soft tissues such as muscles are also fossilized. However, locating such tissues remains particularly difficult due to the limited contrast attained in optical microscopy and to the limits of tomography[1], two techniques that are today commonly used to study fossils.

Now, researchers from CNRS, the French Natural History Museum (MNHN) and the SOLEIL synchrotron have designed and developed a novel non-destructive approach based on the localization of rare earths. These chemical elements (yttrium and the lanthanides) are known to exist in fossils in trace amounts, typically from 1 to 1000 micrograms per gram of material. However, depending on the type of tissue, the quantity of trace elements incorporated during fossilization varies. Such preferential deposition makes it possible to distinguish between the anatomical parts of a fossil. This appears as a strong contrast between different chemical elements according to the types of fossil tissue, when the fossil is characterized using synchrotron fast X-ray fluorescence imaging[2]. To speed up the analysis, the team proposes a rapid method for differentiating tissue, based on the probabilistic nature of the data measured.

[1] Tomography is a technique based on the reconstruction of virtual cross-sections of a 3-dimensional object from a large number of X-ray images.
[2] X-ray fluorescence is the secondary X-ray emission from atoms bombarded with X-rays. The emission spectrum is characteristic of the chemical elements making up the sample. Used in imaging mode, it can be used to locate these elements. In this study, the very high intensity of the synchrotron radiation makes it possible to access elements present in trace amounts, which is unachievable with laboratory X-rays.

The scientists applied this approach to three fossils (two fishes and a shrimp) discovered in Morocco and dating from the Upper Cretaceous, around 100 million years ago. The contrasts revealed using this method enabled them to distinguish between hard tissues (bones and shells) and soft tissues (muscles and other fossilized organs). In particular, this enabled them to discover the previously hidden anatomical features of a fossil fish of which only one specimen is known, one of whose skull bones is in the form of a wide, notched blade.

This new approach makes it possible to obtain a detailed, accurate view of the anatomy of a fossil without damaging it and without the need for prior delicate sample preparation. It is particularly suitable for flattened fossils given that X-rays penetrate the fossil to a depth of a few fractions of a millimeter. The technique also revealed certain bones concealed under a fine layer of rock, enabling them to be viewed directly. For instance, it enabled certain concealed appendages of a fossil shrimp to be viewed, such as the legs and the antennae, which hold important information for the study of its relationship to other shrimps. In addition, rare earth content reflects the environment in which a fossil is preserved, such as connectivity to surrounding water networks, local physico-chemical conditions, and the properties of the mineral phases making up the fossils, thus enabling them to be better described.

The work should therefore facilitate the interpretation of flattened fossils, which are very common in the fossil record. It opens up new prospects not only for paleoenvironmental studies but also for a better understanding of long-term fossilization processes.

The research was carried out as part of the IPANEMA research platform, inaugurated on 12 September 2013 by Geneviève Fioraso, French Minister of Research and Higher Education. IPANEMA is a joint unit of CNRS and the French Ministry of Culture and Communication, set up in partnership with the French National History Museum, with support from the SOLEIL synchrotron which hosts it, and the European Commission (FP7 CHARISMA project).

Reference

Trace elemental imaging of rare earth elements discriminates tissues at microscale in flat fossils, Pierre Gueriau, Cristian Mocuta, Didier B. Dutheil, Serge X. Cohen, Dominique Thiaudière, The OT1 consortium, Sylvain Charbonnier, Gaël Clément & Loïc Bertrand. *PLoS ONE*, 29 January 2014.

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